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Herpetofaunal and Small Mammal Assemblages Along a Terrestrial Moisture Gradient in Northern Virginia

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ABSTRACT

We studied the composition of terrestrial amphibian, reptile, and small mammal assemblages in five types of forested habitats in Prince William Forest Park (PWFP) in northern Virginia ranging from hydric to xeric moisture regimes. We used drift fences and pitfall traps to capture 1,099 individuals representing seven species of anurans, seven salamanders, three lizards, four snakes, four shrews, and four rodents. The wetter floodplain and mesic sites supported significantly higher numbers of amphibians than the three drier sites (mixed, oak, pine). Numbers of *Plestiodon fasciatus*, the only reptile captured in abundance, were not significantly different among all five sites. Number of captures of three species of mammalian insectivores documented at all five sites did not differ significantly. No rodent species was abundant on these sites, although more *Peromyscus leucopus* were captured than other species; it occurred most often in the mesic site. The pine (xeric) site had the fewest species and the lowest number of individuals of all the vertebrate groups. The regenerated forest in PWFP should allow long-term persistence of the herpetofauna and small mammals characteristic of this region.

Key words: Amphibians, community ecology, forest ecology, reptiles, restoration, small mammals, Virginia.

INTRODUCTION

The Coastal Plain and Piedmont regions of the mid-Atlantic have been included traditionally as part of the Oak-(Hickory)-Pine Forest Region, with oaks and hickories comprising the climax community (Braun, 1950; Kuchler, 1964; Skeen et al., 1993). Although accuracy of this designation has been questioned (Monett & Ware, 1983; Ware, 1991) and other types of designations have been proposed (e.g., the ecosystem approach, Bailey, 1995; Ricketts et al., 1999), the fact remains that little to no old growth forest existed in this area for over a century. Elimination of original forests by agriculture, logging in the 1800s and early 1900s, urbanization, and logging in the 20th century have left only patches of forest in varying stages of ecological succession (Godfrey, 1980). Where forest regrowth has occurred on abandoned lands, the result is a mix of forest types ranging from pine on xeric sites to upland hardwoods to mixed hardwood communities in mesic and riparian sites. These forest types provide diverse environments that support mixed assemblages of terrestrial vertebrates. Species richness and relative abundances of these assemblages vary among forested and non-forested habitats and over a range of geographic areas (Kirkland, 1990; Bellows & Mitchell, 1999; Mitchell, 2014).

On Shenandoah Mountain, Virginia, high elevation amphibian and small mammal assemblages vary significantly among clearcut, pine, mature, and old growth forest habitats (Mitchell et al., 1997). In central Virginia, small mammal assemblages show higher

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species richness and greater abundances in oldfield habitats than in hardwood forests (Pagels et al., 1992). Amphibians exhibit the opposite relationships in the same area (Mitchell, 2014). These and other studies (e.g., Buhlmann et al., 1993; Erdle & Pagels, 1995; Bellows & Mitchell, 1999) demonstrate that there is considerable geographic variation in the structure of terrestrial vertebrate assemblages in intact and altered forest ecosystems in the mid-Atlantic region.

We studied the composition of terrestrial amphibian, reptile, and small mammal assemblages in five different types of forested habitats in a national park in northern Virginia. The forests in this national park are unlikely to be subjected to silvicultural practices typical of private, commercial, and military lands where there are active forestry programs. Our objective was to elucidate the structure of these vertebrate assemblages along a moisture gradient ranging from a moist floodplain forest to a xeric pine stand. We hypothesized that there would be fewer species in the driest habitat and that alpha diversity and numbers of individuals would vary among all habitats.

MATERIALS AND METHODS

Study Sites

We established study sites in five different forest types in Prince William Forest Park (PWFP), Prince William County, Virginia. The five sites, described below, were located within the Quantico Creek watershed.

Floodplain – This site was located on a riparian floodplain on the south side of the North Fork of Quantico Creek. The soils were moist to wet during most of the survey period. Tulip tree (*Liriodendron tulipifera*) and river birch (*Betula nigra*) were the dominant canopy trees. Less abundant canopy trees included sycamore (*Platanus occidentalis*) and red maple (*Acer rubrum*). Subcanopy trees were American hornbeam (*Carpinus carolinensis*) and paw-paw (*Asimina triloba*). This site was the only location with herbaceous ground cover (e.g., spring beauty [*Claytonia virginica*], slender toothwort [*Cardamine augustata*], and southern lady-fern [*Athyrium asplenoides*]).

Mesic – American beech (*Fagus grandifolia*) dominated the canopy at this site and produced much of the leaf litter on the deep moist soils. Other canopy trees included white oak (*Quercus alba*) and tulip tree. Red maple, flowering dogwood (*Cornus florida*), and holly (*Ilex opaca*) characterized the understory. The herbaceous layer was sparse with Christmas fern (*Polystichum acrostichoides*) and running cedar (*Diphasiastrum digitatum*). A small intermittent tributary of the North Fork of Quantico Creek was adjacent to this site.

Mixed Hardwood and Pine – This site was on a ridge and in a late stage of ecological succession with mature hardwoods replacing the aging and dying Virginia pine (*Pinus virginiana*). Pines and hardwoods occurred in roughly equal numbers. Dominant hardwoods were southern red oak (*Quercus falcata*), blackjack oak (*Q. marilandica*), and chestnut oak (*Q. montana*). The understory consisted of saplings of these hardwood species. The forest floor was a mix of hardwood leaves and pine needles, and much woody debris. The soil was dry during the majority of the sampling period except during heavy rains.

Mixed Oak - The dominant trees at this site were white oak, American beech, hickory (*Carya* sp.), and red maple with flowering dogwood and American holly in the understory. The relatively dry forest floor was a mix of hardwood leaves and patches of running cedar and ground pine (*Dendrolycopodium obscurum*). The site was located on a gentle slope above a small, unnamed intermittent stream. The soil remained dry during most of the study.

Pine – This highly xeric habitat was located on a flattened ridge area well away from water sources. Virginia pine dominated numerically, with understory trees southern red oak, blackjack oak, white oak, and American beech. The forest floor was covered by pine needles, with several patches of lichen (*Cladonia* sp.). The soil was dry during this study and often hard packed. This site may be an early stage of the mixed hardwood-pine stage, but the soils here were very dry and succession would have to occur over a long period of time.

Methods

We used the drift fence/pitfall technique to capture amphibians, reptiles, and small mammals (Campbell & Christman, 1982; Mitchell et al., 1997). Four arms of aluminum flashing (0.61 m x 7.5 m) were installed upright in a cross configuration with each arm of the array separated from the center of the array by about 7.5 m of open space. At the midpoint of each arm we buried one 19 L (5 gallon) plastic bucket and at both ends of each arm we buried two 3.8 L (#10) cans, one on each side (four total). Thus, each drift fence/pitfall trap array contained 20 pitfalls, each of which had a solution of water and 10-25% dilute formaldehyde to prevent specimens from decomposing, being scavenged by raccoons, and consumed by animals such as shrews (*Blarina*, *Sorex*), and to preserve the vertebrates for additional studies. One array was installed at each of the five sites. Traps were checked every 3-4 weeks from 28 January 1988 to 7 July 1989 for a total of 24 sampling periods. Trap day totals were calculated as the number of days traps were operational multiplied by the number of pitfall traps. We follow Mitchell et al. (1997) in counting the two 3.8 L cans at each end of each fence as one pitfall trap. Thus, the total number of pitfalls per array was four 19 L buckets and eight pairs of 3.8 L cans (12 "pitfalls" per site). Number of trap days per site was 6,312 (31,560 total).

We used Chi-square tests to determine if the number of captures differed significantly among sites (Zar, 1999). We used number of captures because trapping effort was equal for all sites. Herpetofaunal names follow Crother (2012), small mammal names follow Bradley et al. (2014), and plant names follow Weakley et al. (2012).

RESULTS

A total of 895 individuals representing 14 amphibian species (7 anurans, 7 salamanders) was captured during this study (Table 1). The number of species was highest in the floodplain (14) and mixed sites (10), whereas eight species were captured in the mesic and oak sites. The fewest species (7) were recorded on the pine site. Juveniles of four species of *Lithobates* (*L. catesbeianus, L. clamitans, L. palustris, L. sylvaticus*) comprised most of the anuran captures. The latter three were significantly more abundant in the floodplain and mesic sites than the other three sites (Table 1). The toads (*Anaxyrus americanus*) were mostly adults and more numerous on the floodplain, mesic, and mixed sites than in the two xeric sites (Table 1). The pine site had the fewest species and the lowest number of individuals.

All seven salamander species captured in this study were present at the floodplain site (Table 1); the other sites had only 1-3 species each. Numbers of salamanders were higher in floodplain and mesic sites than in the three drier sites (Table 1). The two wetter sites supported significantly higher numbers of salamanders than the three drier sites. The fewest species and the lowest number of individuals occurred at the pine site. Except for two captures on the oak site, most *Ambystoma maculatum* were detected only in the floodplain. Numbers of *Plethodon cinereus* captures were highest on the mesic site (168) and lowest on the pine site (8).

We captured 31 lizards comprising three species and 18 snakes comprising four species in the five study sites. Except for one species, the small numbers of captures precluded statistical comparisons. Only *Plestiodon fasciatus* was present in all five sites: nine in the mesic site, six in the oak site, and four each in the floodplain, mixed, and pine sites. Number of captures among sites were not significantly different (χ^2 = 3.556, P = 0.4695). We captured one *Plestiodon laticeps* on the floodplain and two on the pine sites, and one *Sceloporus undulatus* in mixed and oak sites. A single individual of two species of snakes was captured in the study sites: *Coluber constrictor* (oak) and *Thamnophis sirtalis* (mesic). We captured one *Carphophis amoenus* at two sites (floodplain, oak) and one *Diadophis punctatus* at three sites (floodplain, mesic, mixed).

We captured four species each of shrews and rodents in this study (Table 2). Mammal species richness varied from four at the pine site (3 shrews, 1 rodent) to seven in the floodplain (4 shrews, 3 rodents) and mesic sites (3 shrews, 4 rodents). Of the 155 small mammals, 76.8% were shrews and 23.2% were rodents. Shrews were dominated numerically by *Blarina brevicauda* (39.5%) and *Sorex hoyi* (42%). Insectivores were significantly fewer at the pine site. Three species tested statistically did not differ significantly in number of captures among all sites (Table 2). No site yielded many rodents, but *Peromyscus leucopus* was most abundant, especially at the mesic site. The pine site yielded only one *P. leucopus*. The one *Condylura cristata* was caught in the floodplain forest.

DISCUSSION

The number of amphibian species captured by the drift fence/pitfall technique was about half of those expected for northern Virginia. The seven species of frogs represented 50% of expected and the seven species of salamanders represented 64% of expected (Mitchell & Reay, 1999). The majority of anurans captured were metamorphs and juveniles and the majority of salamanders were adults. This pattern is similar to captures obtained during a drift fence/pitfall study in old field and mixed hardwoods in central Virginia (Mitchell, 2014). Fifty-seven percent of the expected species of shrews and moles and 40% of the expected mice and chipmunks were captured with this technique in the five habitats studied (Linzey, 1998). Small mammal species obtained in central Virginia were the same as those captured by Pagels et al. (1992) and the upper Coastal Plain by Bellows & Mitchell (1999, 2000).

Table 1. Species richness and relative abundance of amphibians in five forested habitats in northern Virginia. Raw numbers are provided and analyzed because capture effort was the same for all habitats. FP = floodplain, Mes = mesic, Mix = mixed. NT = not tested due to small sample size.

Species	Common Name	FP	Mes	Mix	Oak	Pine	Total	χ^2	P
Anurans									
Acris crepitans	Northern Cricket Frog	3	3	3	0	1	10	4.00	0.4060
Anaxyrus americanus	American Toad	24	31	22	5	8	90	27.22	<0.0001
Pseudacris crucifer	Spring Peeper	6	0	2	4	1	13	8.92	0.0631
Lithobates catesbeianus	American Bullfrog	36	1	2	1	0	40	122.75	<0.0001
Lithobates clamitans	Green Frog	73	41	21	5	1	141	124.14	<0.0001
Lithobates palustris	Pickerel Frog	76	39	9	4	3	131	151.56	<0.0001
Lithobates sylvaticus	Wood Frog	22	12	1	3	1	39	42.92	<0.0001
No. Species		7	6	7	6	6	7		
Subtotal		240	127	60	23	15	465	374.60	<0.0001
No./trap day x 100		4.83	2.56	1.21	0.46	0.31			
Salamanders									
Ambystoma maculatum	Spotted Salamander	21	0	0	2	0	23	15.96	<0.0001
Ambystoma opacum	Marbled Salamander	2	1	0	0	0	3	NT	
Eurycea bislineata	Northern Two-lined Salamander	5	0	0	0	0	5	NT	
Eurycea guttolineata	Three-lined Salamander	15	0	0	0	0	15	NT	
Hemidactylium scutatum	Four-toed Salamander	2	0	1	0	0	3	NT	
Plethodon cinereus	Red-backed Salamander	77	168	77	49	8	379	182.31	<0.0001
Plethodon cylindraceus	White-spotted Slimy Salamander	1	0	1	0	0	2		
No. Species		7	2	3	2	1	7		
Subtotal		123	169	79	51	8	430	181.58	<0.0001
No./trap day x 100		2.47	3.40	1.59	1.02	0.16			
Total		363	296	139	74	23	895	472.10	<0.0001
Number of species		14	8	10	8	7	14		

Table 2. Species richness and relative abundance of small mammals in five forested habitats in northern Virginia. Raw numbers are provided and analyzed because capture effort was the same for all habitats. FP = floodplain, Mes = mesic, Mix = mixed. NT = not tested due to small sample size.

Species	Common Name	FP	Mes	Mix	Oak	Pine	Total	χ^2	P
Insectivores									
Blarina brevicauda	Northern Short-tailed Shrew	9	10	10	13	5	47	3.53	0.473
Condylura cristata	Star-nosed Mole	1	0	0	0	0	1	NT	
Sorex hoyi	American Pygmy Shrew	9	10	11	16	4	50	7.40	0.116
Sorex longirostris	Southeastern Shrew	4	4	8	3	2	21	4.95	0.292
No. Species			4	3	3	3	3	4	NT
Subtotal		23	24	29	32	11	119	10.87	0.028
#/trap day x 100		0.46	0.48	0.58	0.64	0.22			
Rodents									
Microtus pennsylvanicus	Meadow Vole	2	1	3	2	0	8	3.25	0.517
Peromyscus leucopus	White-footed Mouse	3	3	13	1	2	22	21.64	0.0002
Tamias striatus	Eastern Chipmunk	0	1	0	0	0	1	NT	
Zapus hudsonius	Meadow Jumping Mouse	3	2	0	0	0	5	NT	
No. Species		3	4	2	2	1	4		
Subtotal		8	7	16	3	2	36	17.06	0.0019
#/trap day x 100		0.16	0.14	0.32	0.06	0.04			
Total		31	31	45	35	13	155	17.29	0.0017
Number of species		7	7	5	5	4	8		

Land-use history plays an important, if not dominant, role in the compositional variation of forests and species use of regrowth forest in northern Virginia. The 7,000 ha PWFP, established in 1937 as a recreational area, is an example of the potential for regrowth of forests to maintain and enhance the recovery of native fauna. Its history includes a succession of Native American inhabitants, charcoal production for iron, land clearing during the Civil War, various types of agriculture and pasture, and finally land reclamation by the Civilian Conservation Corps in the early 1930s (Orwig & Abrams, 1994; Potomac Appalachian Trail Club, 2015). Natural succession and reforestation since the 1930s have created a mosaic of habitats, much of it in forest cover, allowing us to select a range of habitat types for study.

Contrasting habitats of forest (mesic) versus non-forest (xeric) allowed us to gain insight into the composition and habitat distribution of these vertebrate assemblages before the land was cleared historically for agriculture and timber. Several studies conducted in Virginia have demonstrated that old fields are used extensively by insectivores and rodents, but not amphibians and some reptiles. Studies at forested and old field sites in central Virginia are an example of this contrast (Pagels et al., 1992; Mitchell, 2014). Small mammal species richness and abundance is higher in old fields than in hardwood forests on Fort A.P. Hill in Caroline County (Bellows et al., 1999, 2001) and higher in logged forests than unlogged forests in the southwestern Virginia Piedmont (Shively et al., 2006). In contrast, amphibian species richness and abundance is higher in forested habitats than logged or old field habitats in central Virginia (Mitchell, 2014), the southwestern Piedmont (Fredericksen et al., 2006; Burress et al., 2011), mountains in western Virginia (Mitchell et al., 1997), and southeastern Virginia (Buhlmann et al., 1994).

The primary environmental feature that influences alpha diversity and population sizes of amphibians in Prince William Forest Park forests is soil moisture. More species and individuals were captured in moist sites than in drier sites, an expected result because of amphibian moisture requirements (Duellman & Trueb, 1986). Reduced soil moisture is correlated to higher environmental temperatures that together create conditions unsuitable for most amphibians. The differences we observed in species richness and relative abundance among these habitats is generally consistent with results of numerous other studies. Salamander abundance was significantly higher in wetter old growth forests than in drier recent clear-cuts in Missouri (Herbeck & Larsen, 1999), New Brunswick (Waldick et al., 1999), and Vancouver Island in Canada (Dupuis et al., 1995). More amphibians were found in hardwood forests than in cutover, pine, and recently burned sites in Delmarva (McLeod & Gates, 1998), on recent clear-cut sites in Craig and Montgomery counties in Virginia (Bylmer & McGinnes, 1977), and in mixed pine-hardwood sites in Arkansas (Loehle et al., 2005). Clear-cut forests and pine stands which usually occur on dry soils are unable to retain enough soil moisture to meet the moisture requirements of most amphibians.

Composition of reptile assemblages in forest habitats was as variable as the composition of trees, subcanopy, and herbaceous vegetation. Few reptiles were captured with the drift fence/pitfall trap arrays used in this study because small pitfalls are not effective in capturing most reptiles. We did not use funnel traps, a standard technique for capturing terrestrial reptiles, especially snakes (Fitzgerald, 2012), because we were unable to be present at the site every day. Even though the number of captures was small, the pattern of captures for lizards versus snakes followed results of other studies. Numerically, we found more lizards on the drier mixed and pine sites than in the floodplain and mesic sites. More snakes were found on floodplain and mesic sites compared to the three drier sites. These results differ from that found by Clawson et al. (1984) in Missouri. In their study using pitfalls and funnel traps, *Plestiodon fasciatus* and *P. laticeps* occurred in greater abundance in upland forest (mesic) than in old-field (xeric) sites and more *Coluber constrictor* and *Diadophis punctatus* occurred in old-fields than in upland forests. Our results are similar to those of Mitchell (2014), who captured more lizards in old-fields than in hardwood forests in central Virginia. Snake species richness was similar in old-fields and hardwoods but more individuals were captured in the latter habitat type. However, the small sample sizes preclude definitive generalizations. More reptiles (lizards and snakes combined) occur on harvested, open canopy, and clearcut sites than on unharvested hardwoods with full canopy (Adams et al., 1996; McLeod & Gates, 1998), primarily due to their need for sunlight to aid in thermoregulation.

Small mammal species found primarily in grass-dominated habitats (e.g., *Cryptotis parva*, *Reithrodontomys humulis* (Bellows et al., 2001) were not present in our study. All three species of insectivores and rodents captured by McLeod & Gates (1998) in Maryland occurred in hardwood, clear-cut, pine, and burned sites. Ground cover was much higher in their pine and burned sites, but number of captures did not differ substantially from those in the hardwoods and clear-cuts. Kirkland et al. (1996) found significantly more shrews and rodents in an unburned than in a burned hardwood forest in Pennsylvania.

Except for *Peromyscus leucopus* which occurred in both habitat types, more small mammals were captured in logged than unlogged hardwood forests in Franklin County, Virginia (Shively et al., 2006). *Peromyscus leucopus* is a habitat generalist that can tolerate variable environmental conditions (Linzey, 1998). More individuals of both groups occurred in old-fields than hardwood forests in the central Virginia Piedmont (Pagels et al., 1992) and on Fort A.P. Hill in the upper Coastal Plain (Bellows & Mitchell, 1999). Their old-fields had more abundant herbaceous cover and woody debris than the unlogged sites, features favorable to most small mammals (Kirkland et al., 1985).

The mixed hardwood and pine forest now characterizing Prince William Forest Park and much of northern Virginia resulted from ecological succession of former farmland largely devoid of forest cover throughout the 1800s into the 1920s. The land in this area was extensively farmed and logged and likely only patches of secondary forest were standing when the park was created in 1937 (Potomac Appalachian Trail Club, 2015). Reforestation to native forests usually results in recovery of herpetofaunal assemblages. For example, reforestation of former agricultural sites resulted in a 68% recovery of the native reptile fauna in the limestone region of Puerto Rico (Ruiz-Jaen & Aide, 2005). The range of variation in forest and herbaceous cover, moisture, and temperature in the restored sites in PWFP likely has accounted for the variation in the response of amphibians, reptiles, and small mammals to the changing conditions.

The management approach of the National Park Service to interfere as little as possible with forest regrowth has resulted in a mosaic of forest cover types that are used in different ways by amphibians, reptiles, and small mammals. The age and composition of these forest types have been influenced by geographic variation in soil moisture and site history, but they were generally allowed to develop naturally with little to no management. The forest in PWFP derived from restoration and natural regrowth should allow long-term persistence of the herpetofauna and small mammals characteristic of this region. Quantico Marine Corps Base, which abuts the park on the south side, is also largely forested, thus making these two areas a habitat island within the expansive urban development surrounding it.

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